Lithium-ion Batteries for providing Virtual Inertia

Presenter:
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Agenda
- Motivation
- Ancillary services
- Research Project - ReserveBatt
- Virtual Synchronous Machine
- Virtual inertia response of a multi VISMA system
- Battery requirements
- Experimental results of the battery
- Summary and further steps of the project
Motivation

- Providing power and inertia
  - stable power supply
  - equilibrium
- Decrease of conventional power plants
- Inertia is especially used for damping fast frequency changes
- Virtual inertia with inverters provided by high power batteries

Ancillary services

Fundamental differentiation from ancillary services in frequency stability

1. Proportional power to the frequency gradient:
   - rotating mass \( \rightarrow \) provide inertia for damping the initial frequency change
     - \( P \sim \frac{d\phi}{dt} \)
     - D controller

Fig.1: Physical effect and general functionality of the synthetic inertia in the frequency response

Fig.2: Effect and arrangement of the instantaneous reserve in the frequency response \([1]\)
Ancillary services

Fundamental differentiation from ancillary services in frequency stability

2. Proportional power to the frequency deviation:
   - primary (black) and long term stability mechanism
     - \( P \sim \Delta f \)
     - \( P \) controller

Fig. 2: Effect and arrangement of the instantaneous reserve in the frequency response [1]

Research Project - ReserveBatt

- 400 kVA battery-inverter demonstrator
- VSG algorithm
  “Virtual Synchronous Machine (VISMA)”
- Battery substitutes the energy of rotating masses
- Design and evaluation of utilization options and future business models
Virtual Synchronous Machine (VISMA)

Virtual inertia response of a multi VISMA system

- Response of VISMA system on frequency drop

\[ H = \frac{E}{S} \]

\( H \) - inertia constant
\( E \) - kinetic energy of the generator turbine system
\( S \) - rated apparent power

Fig. 3: Fundamental set-up of the Virtual Synchronous Machine [2]

Fig. 4: Frequency response for three different experimental setups [4]

Fig. 5: Circuit diagram of laboratory setup
Battery requirements

- High frequency changes → fast power response
- Economical aspects → small batteries
  → High current rates
- Necessity to charge as well as to discharge
  → operating range around 50% State of Charge

General battery aging measurements

- Measurements with LFP batteries
- Different SOCs and DOD ranges

Equivalent Full Cycles, 40°C, current rate of 2C
General battery aging measurements

- Measurements with NMC batteries
- Different SOCs and DOD ranges

Equivalent Full Cycles, 30°C, current rate of 1C

Fig. 7: Battery aging measurements of NMC batteries

Summary and further steps of the project

- LFP batteries probably not good to use around 50% SOC → NMC
- Economic usage of li-ion batteries for ancillary services are strongly dependent on their application

- Grid simulation ↔ longer measurement periods
- Power profiles ↔ simulations and aging measurements
- Power plant performance 400kVA inverter
Thank you for your attention!

- Patent:

- Literature:
  [5] Further literature is deposited in the full paper

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Grid analyses

- Load Profile stochastics for the virtual synchronous generator
- Simulation from measurements
- Possible loads on a battery system
- 400kVA converter system